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APPARATUS FOR MEASURING THE VELOCITY OF PROJECTILES

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APPARATUS FOR MEASURING THE VELOCITY OF PROJECTILES

by

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ABSTRACT

The following report concerns the design, construction and operation of equipment used to measure projectile velocities. Its evaluation in testing sporting ammunition was deemed thoroughly satisfactory.

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APPAREIL POUR MESURER LA VÉLOCITÉ DES PROJECTILES

par

E. Nagy* et E. Contestabile**

SOMMAIRE

Le présent rapport a pour objet le modèle, la fabrication et le fonctionnement d'un appareil utilisé pour mesurer la vélocité de projectiles. La valeur de cet instrument lors d'essais faits avec des munitions pour le sport s'est avérée très satisfaisante.

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APPARATUS FOR MEASURING THE VELOCITY OF PROJECTILES

The following report concerns the design, construction and operation of equipment used to measure projectile velocities.

REQUIREMENTS

It is necessary to measure the projectile velocity in two routine tests performed at CERL. The first of these tests involves measuring the velocities of bullets, of new and reloaded sporting ammunition for authorization purposes. These tests are performed in an indoor firing range, and involve different calibres from different manufacturers. The velocity range is from 200 m/s to 1200 m/s.

The second test requires measuring the velocity of .50 cal projectiles used in determining the impact sensitivity of explosives. The velocities of these 12.5 mm diameter by 12.5 mm long projectiles range from 100 m/s to 500 m/s. The test is performed outdoors.

EQUIPMENT

The instrument has basically two components; the bullet detectors and the velocity-determining circuitry. A photograph and a cross-section of the detectors are shown in Fig. 1 and Fig. 2, respectively. Five phototransistors are mounted on Delrin stock and enclosed in an aluminum case having a plastic window. Since these detectors are used outside, they are made to fit into a brass slide that is bolted on a channel, thus allowing for easy removal. For protection, thick steel bullet deflectors are mounted just ahead of the detectors. This is seen in Fig. 3. In the set-up used indoors, lamps mounted on a frame bolted to the bullet deflectors provide light for the detection system.

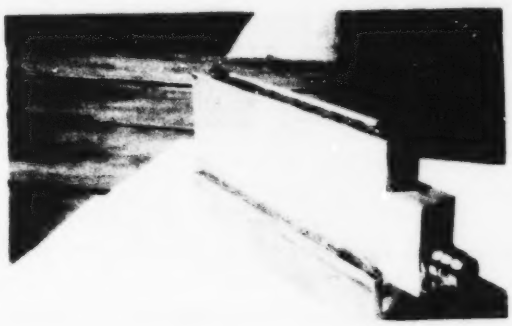
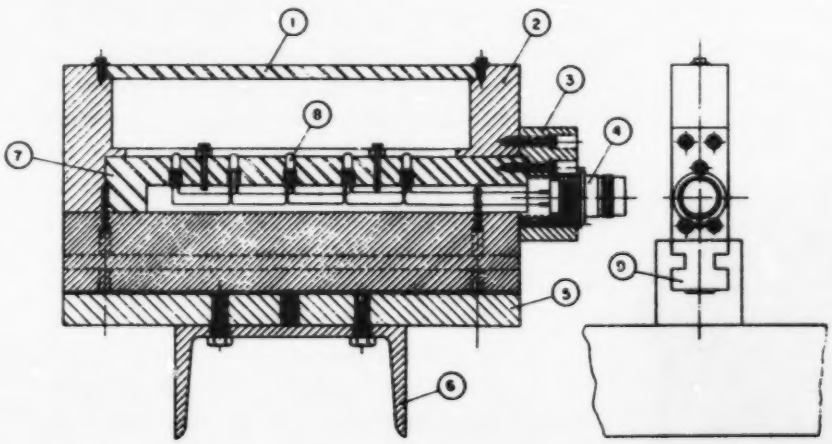


Fig. 1 - Photograph of projectile detectors

PROJECTILE DETECTOR PARTS LIST



1. Plastic window
2. Aluminum case
3. Aluminum block
4. Electrical connector
5. Brass base
6. Aluminum channel
7. Delrin detector holder
8. Detector (Q-ty 5)
9. Aluminum slide

Fig. 2 - Cross-section of detectors

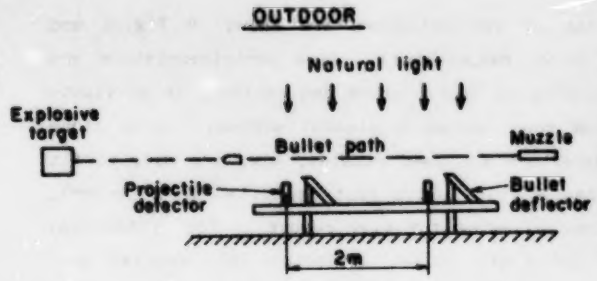


Fig. 5 - Rear view of cabinet

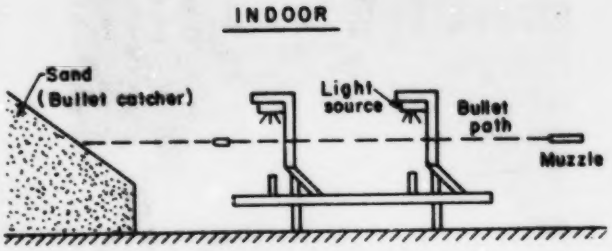


Fig. 3 - Detectors and bullet deflectors mounted on channel

The velocity determining circuitry is mounted in a cabinet, a photograph of which is shown in Fig. 4. Through the proper selection of a front panel switch, projectile velocities can be measured over multiples of 2 and 10 units of distance. One, two-wire, shielded cable is required to connect each detector to the instrument. See Fig. 5.

Fig. 4 - Front view of cabinet

OPERATION

To operate the instrument, simply locate the detectors a convenient distance apart on the aluminum channel and position the assembly at a distance from the muzzle of the gun so that the air blast will not influence the velocity readings. For consistent projectile velocity readings, the gun's line of fire should not be more than 25 cm above the detection window. When using the system indoors, the firing line should be centered between the detection window and the source of light.

Since the same recorder is used for the indoor and outdoor testing facilities, there are two sets of connectors and a selector switch on the back panel. The switch allows one to select between the outdoor or indoor detectors. Two twinax (two shielded wires) cables are required to connect the detectors to the recorder. The cable from detector 'A', the detector closest to the gun, goes to the 'start' connector and the other, detector 'O', goes to the 'stop' connector. A switch on the front panel allows one to select the separation distance corresponding to that of the detectors. This causes the unit to display readings in the appropriate units.

When ready to start, turn the equipment on and allow a few minutes for warm-up. Press the reset button on the front panel and the gun may now be fired. The unit will display the measured velocity. The display hold switch can be turned on to prevent any spurious retriggering.

THE CIRCUIT

The electronic circuitry is basically comprised of the analog and the digital sections shown in Fig. 6 and Fig. 7. When a projectile is fired over the sensors, it is detected by the five phototransistors. The generated signal from each detector is then filtered, amplified and digitized. The two active filters (using an LM102)

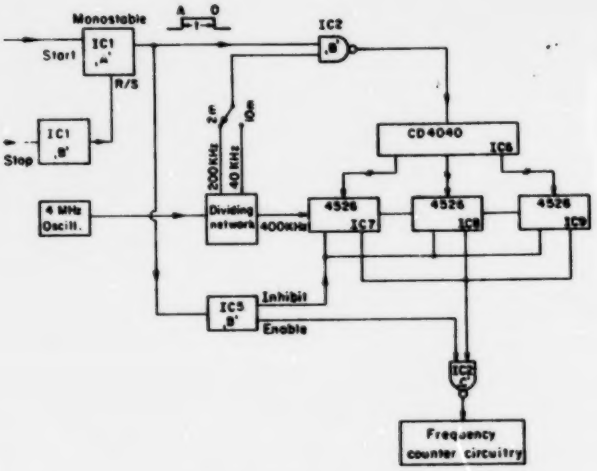


Fig. 6 - Block diagram of digital circuit

employed are both high pass filters having a cut-off frequency of 2 KHz. They will filter 60 Hz interference and prevent false triggering due to any slow moving objects traversing the viewing window of the sensors.

The signal now enters the digital section which is comprised of a measuring and a frequency counting circuit. The following outline of the operation of the circuit will make reference to Fig. 8, a block diagram of the digital section.

When an event is sensed by detector 'A', the output of the monostable multivibrator will go high and when it is sensed by detector '0', its output will go low. The pulse generated will thus have a width t, corresponding to the time of flight of the projectile over the detectors. This pulse is then used to gate the output of a 200 KHz oscillator. The number of pulses, n, gated is given by, $n = 200\,000\ t$. These pulses are counted and retained by the binary counter CD 4040. Since $t = d/v$, where d is the distance between detectors and v is the projectile velocity, the velocity can be determined if d is given. With $d = 2$ m, $v = 2/t$.

Next, the output of a 400 KHz oscillator is divided by the above retained binary number, n. This is accomplished by a CD 4526, a divide by n counter, which output frequency will be $f = 400\,000/n = 400\,000/200\,000\ t = 2/t$. Substituting $t = 2/f$ into $v = 2/t$ gives $v = f$. Therefore this output frequency represents the measured velocity in meters per second.

By selecting d = 10 m via the front panel switch, the 400 KHz source frequency is divided by ten and fed to the gate. The frequency count is then taken as explained for d = 2 m and again the reading represents the velocity in meters per second for a projectile having travelled over detectors spaced 10 m apart.

The frequency counting section is composed of two programmable dividers C 1 and C 2 cascaded together. These divide the 60 Hz line frequency by 60, thereby providing a one second reference to gate the count input of the ICM7217A. The remaining gates shown in the circuit are necessary for storing and resetting the counter.

Considering only the gating of the high frequency, it is possible to obtain a count of n cycles when, in actual fact, the time interval was long enough to allow n + 2 cycles to be counted. This is due to the manner in which the counters is triggered to start and to stop (ie. on the same slope). Without considering any other small timing errors that may arise between the analog circuitry of each detector, the maximum expected error is 0.05% at 100 m/s, 0.5% at 1000 m/s, and 1% at 2000 m/s.

CIRCUIT EVALUATION

The circuit was extensively tested with the .17 cal ammunition and using ambient light. To solve some initial problems regarding EMF interference and muzzle blast, the cables were better shielded and the detector bodies were manufactured from metal and made and mounted more rigidly. A problem arose with the outdoor set-up when the sun was directly above the detectors. By

adding an extra amplifier stage, this problem has been greatly reduced. It may be necessary at times, when the sun is very bright, to use frosted glass as a replacement for the transparent detector windows.

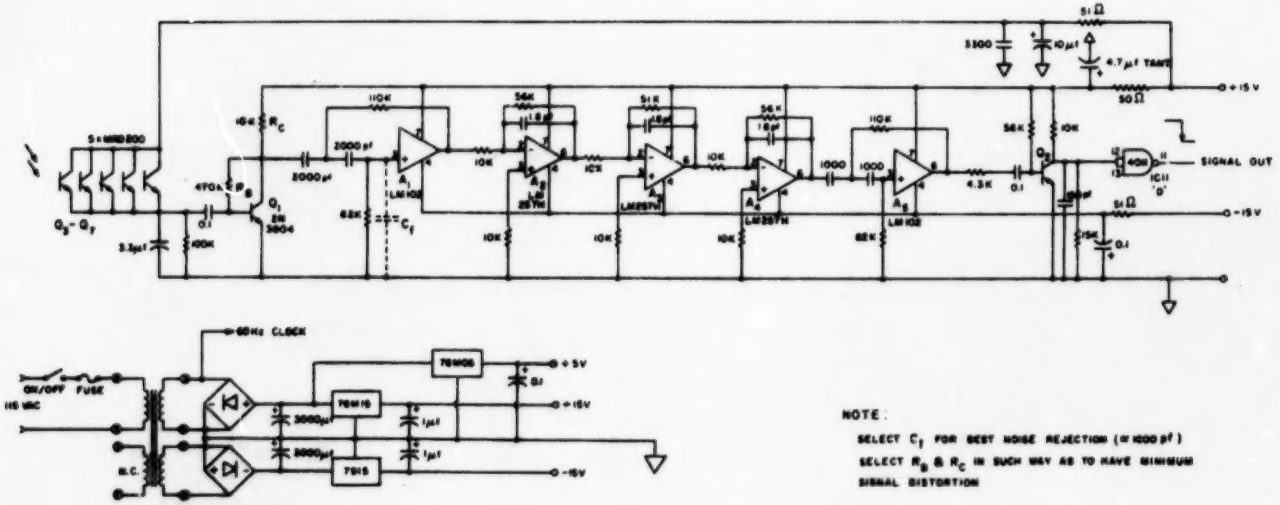


Fig. 7 - Analog circuitry section

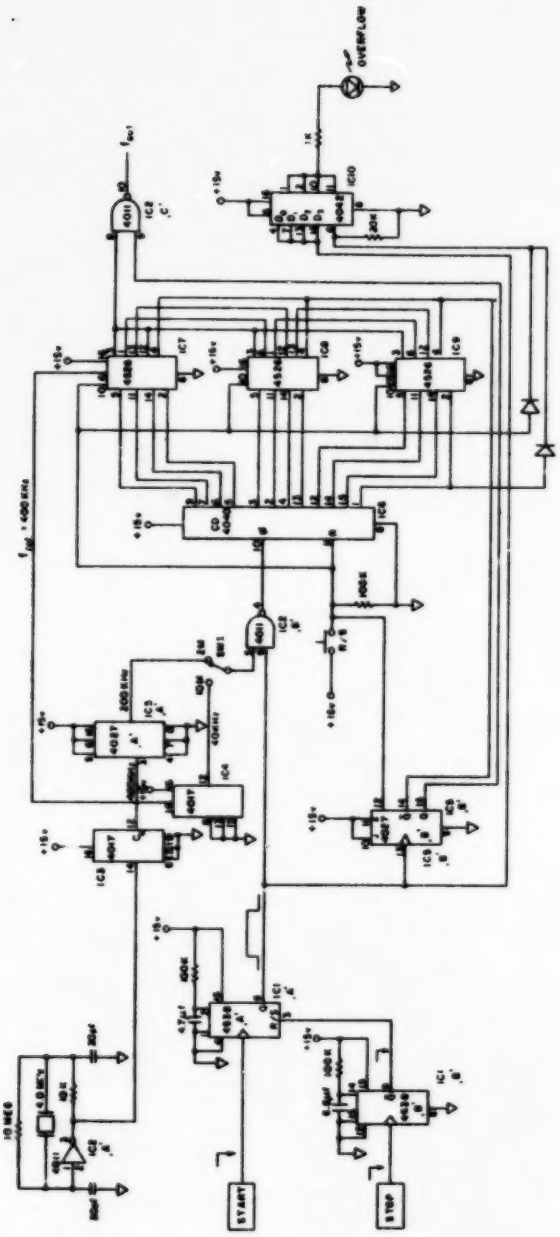


Fig. 8a - Digital circuitry section

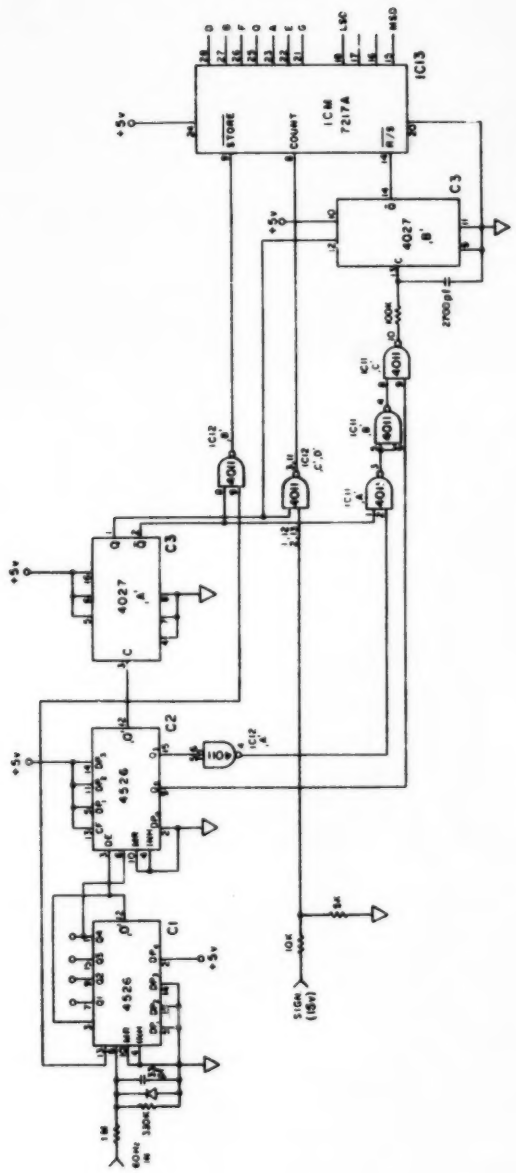


Fig. 8b - Digital circuitry section